should not the President's addresses, which are often, and I am sure in this case, worth more than all the rest of the number, be paged with Christian figures?

My dear Mr. Bentham,
Yours very sincerely,
CH. DARWIN.

HERTZ'S EXPERIMENTS.

I.

"OH! yes; I understand it all now. Electricity is the ether;" or, "Yes; it's just like everything else: electricity is a vibration." These are the remarks one hears made by those who think that a few scattered words picked up at a popular lecture make things quite clear. It is no doubt unfortunate that repeating a form of words is a different matter from understanding them, and still more different from understanding the subject they are intended to explain. In this case there is the added misfortune that the form of words is not accurately repeated, and in its inaccurate form does not mean what is true. It is often hardly worth while remarking this to those who make these statements, because the words convey to them little or no signification, and are to them as true as any other unmeaning sentence. The connection between electricity and the ether is certainly not, as far as is known, well described by saying that "electricity is the ether," and we cannot say with any certainty that electricity is or is not a vibration. Hertz's experiments have given an experimental proof of Maxwell's theory that electrical phenomena are due to the ether, and Hertz's experiments deal with vibrations. One cannot, however, say, because the pressure of 15 pounds per square inch exerted by the atmosphere is due to the air, that therefore "pressure is the air": nor even, because a person who studied the properties of the air had studied them by means of sounds propagated through it, can one assert that "pressure is a vibration." It is to be hoped no one will now assert that "electricity is pressure." The example is given to illustrate the absurdity of the statements made as deductions from recent experiments, and not to teach any new theory. And yet one comes across people who, after listening to an interesting lecture Lord Rayleigh might give, illustrated by Mr. Boys's sound-pressure-meter, would make the above statements, and really think they understood them. That blessed word "Mesopotamia" comforted the soul of an old lady with some reason, for religion is to some extent a question of feeling; but in science it is high treason to truth to be comforted by unmeaning sounds—they should produce despair.

It is to be hoped after this tirade that any reader of these articles who comes across statements he cannot understand will not tell himself the lie that he does understand them, nor pretend to others that he does. The subject is very difficult: one that has engaged the attention of thoughtful and clever men for many years, and is still in many parts, even to the most acute, shrouded with difficulties, uncertainties, and things unknown, so that nobody need be the least ashamed of not following even as far as others can go into this wonderful region. If the articles can give to most who read them glimpses which unfold intelligible ideas of even the outskirts of this region, it is all that any writer can reasonably expect who is not one of those masters of exposition who combine the highest scientific and literary abilities.

Consider for a minute the question at issue. That electric and magnetic phenomena are due to the same medium by which light is propagated—that all-pervading medium by whose assistance we receive all the energy on this earth that makes life here possible, by which we learn the existence of other worlds and suns, and analyze their structures and read their histories; that medium which certainly pervades all transparent bodies, and probably all matter, and extends as far as we know of anything existing: this wonderful all-pervading medium is the one we use to push and pull with when we act by means of electric and magnetic forces; and remember that we can pull molecules asunder by this means, as well as propel trains and light our houses. The forces between atoms are controlled by this all-pervading medium, which directs the compass of the mariner, signals round the globe in times that shame e'en Shakespeare's fancy, rends the oak and terrifies creation's lords in the lightning flash. It was a great discovery that proved all concord of sweet sounds was due to the medium that supplies the means of growth to animals and plants, and deals destruction in the whirlwind; and yet the 80 miles depth of our air is but a puny thing compared with the all-pervading illimitable ether.

That there is a medium by which light is transmitted in a manner somewhat analogous to that by which the air transmits sound has been long held proved. Even those who held that light was due to little particles shot out by luminous bodies were yet constrained to superpose a medium to account for the many strange actions of these particles. Now, no one thinks that light is due to such particles, and only a very few of those who have really considered the matter think that it can be due to air, or other matter such as we know. How does light exist for those eight minutes after it has left the sun and before it reaches the earth? Between the sun and earth there is some matter, no doubt, but it is in far-separated parts. There are Mercury and Venus, and some meteors and some dust no doubt, and wandering molecules of various gases, many yards apart, that meet one another every few days, perhaps, but no matter that could pass on an action from point to point at a rate of thousands of miles each second. Some other medium must be there than ordinary gross matter. Something so suble that the planets, meteors, and even comets—those wondrous fleecy fiery clouds rushing a hundred times more quickly than a cannon-ball around the sun—are imperceptibly impeded by its presence, and yet so constituted as to take up the vibrations of the atoms in these fiery clouds and send them on to us a thousand times more rapidly again than the comet moves to tell us there is a comet toward, and teach us what kinds of atoms vibrate in its tail. How can a medium have these contrary properties? How can it offer an imperceptible resistance to the comet, and yet take up the vibrations of the atoms? These are hard questions, and science has as yet but dim answers to them, hardly to be dignified by the name of answers—rather dim analogies to show that the properties supposed to coexist, though seeming contradictory, are not so in reality. One of the most beautiful experiments man knows—one fraught with more suggestions than almost any hundred others—is that by which a ring of air may be thrown through the air for many yards, and two such rings may hit, and, shivering, rebound. These rings move in curved paths past one another with almost no resistance to their motion, urged by an action not transmitted in time from one ring to another, but, like gravitation, acting wherever a ring may be, and yet the air through which they move *can* take up vibrations from the rings, showing thus that there is no real contradiction between the properties of things moving through a medium unresistedly in certain paths round one another, and yet transmitting other motions to the medium. This same air can push and pull, as when it sucks up water-spouts and deals destruction in tornadoes. Hence there seems no real contradiction between a medium that can push and pull and transmit vibrations, and yet offer no resistance to such fragile, light, and large-extended things as rings of air.

It is important to understand something about the properties that this medium must have in order to explain light, electricity, and magnetism, because there is no use expecting a medium to possess contradictory properties. It is also well to recollect that for about two hundred years the existence of a medium by which light is propagated has been considered as certain, and that it would be very remarkable if this medium, which can be set in vibration by material atoms, acted on matter in no other way. It seems almost impossible but that a medium which is moved by atoms, and which sets them into motion, should be able to move such armies of atoms as we deal with in material bodies. Even if we knew nothing of electricity and magnetism, it would be natural to look for some important phenomena due to the action of this medium on masses of matter. The medium is a *vera causa*, and if it can be shown that the same set of properties by which electric and magnetic forces are explained will also enable it to transmit vibrations that have all the properties of light, it will surely be beyond a doubt but that these electric and magnetic actions are those very ones we would naturally expect from the medium that propagates light. Clerk Maxwell some years ago showed that this was so, but as far as any facts known at that time could prove, there were other theories of electric and magnetic actions which explained their known phenomena without the intervention of a medium. The matter stood somewhat thus. The older theories of electric and magnetic force explained all phenomena then known. These older theories assumed that electric and magnetic forces were propagated instantaneously throughout space. That if the sun became electrified, it would instantaneously begin to induce electricity on the earth. That there would be no delay of eight minutes such as occurs between a light occurring on the sun and its acting on the earth. Similarly in the case of magnetic actions, they were supposed to be propagated instantaneously throughout space. It was, no doubt, known that it took time for an electric signal to be transmitted along a conducting cable. This is, however, a very much more complicated problem than the simple one of supposing a body surrounded by a non-conductor to be electrified. Will it or will it not instantaneously act on all conductors in space, and begin to induce electrification on them? As far as was known, such actions as this, actions through non-conducting space, were instantaneous. Such an instantaneous action could not be transmitted by the air. Air cannot send on from point to point any effect more rapidly than a molecule of air can moving carry it forward, and that is only a little faster than the velocity of sound; and there was every reason to know that electric induction through air was propagated much more rapidly than that. There was every reason to believe that electric and magnetic forces acted without any material intervention.

In fact, in these older theories there was no thought of any medium to transmit the actions; it was supposed that electricity acted across any intervening space instantaneously. There is no real difficulty in such a supposition: as far as we know, gravitation is just such an action, and as far as was then known, there was no experiment that disproved the supposition in the case of electric and magnetic actions. It was known that no experiment had ever been devised that could test whether this action was instantaneous or whether it was propagated at a rate such as that of light. It was known that this action was enormously more rapid than sound, but as light goes about 300,000 times as fast as sound, there was plenty of spare velocity. These older theories explained all that was known, and they supposed nothing as to the existence of an intervening medium. Any theory that assumed that induction was not instantaneous, but that energy having been spent on electrification at one place work would be done at another after some time, as in the case of light generated on the sun not reaching the earth for eight minutes, any theory that assumed such a disappearance of energy at one place and its reappearance at another after the lapse of some time must assume some medium in which the energy exists after leaving the one place and before it reaches the other. A theory that only supposes instantaneous action throughout space need not assume the existence of a medium to transmit the action, but any theory that supposes an action to take time in being transmitted from one place to another must assume the existence of a medium. Now, Maxwell's theory assumed the existence of a medium, and along with that led to the conclusion that electric and magnetic actions were not propagated instantaneously, but were propagated with the velocity of light. According to his theory an electric disturbance occurring on the sun would not produce any effect on the earth for about eight minutes after its occurrence on the sun. No experiments were known to test the truth of this deduction until the genius of Hertz brought some of the most beautifully conceived, ingeniously devised, and laboriously executed of experiments to a brilliantly successful conclusion, and demonstrated the propagation of electric and magnetic actions with the velocity of light, and thereby proved experimentally that they are due to that same wonderful, all-pervading medium, by means of which we get all the energy that makes life here possible.

The problem to be solved was, Are electric and magnetic actions propagated from place to place in a finite time, or are they simultaneous everywhere? How can experiments be made to decide this? Consider the corresponding problem in sound. What methods are there for determining the rate at which sound is propagated? An experiment that measures the rate can tell whether that rate is finite or whether it is infinitely great. There are two important methods employed for measuring the velocity of sound. The second is really only a modification of the first direct method, as will be seen. The direct method is to make a sudden sound at a place, and to find how long afterwards it reaches a distant place. In this method there is required some practically instantaneous way of communicating between the two places, so that the distant observer may know when the sound started on its journey. A modification of the method does not require this. It depends on the use of reflection. If a sound be made at a distance from a reflecting surface, the interval of time between when the sudden sound is made and when the reflected sound, the echo, returns, is the time the sound took to travel to the reflector and back again. A well-known modification of this method can be applied if we can secure a succession of sudden sounds, such as taps, at accurately equal intervals of time. We originate such a regular succession of taps, and alter the distance from the reflector until each reflected tap occurs simultaneously with the succeeding incident tap. Or if the distance at which we can put the reflector be sufficiently great, we may arrange it to be such that a reflected tap is heard simultaneously with the second, third, fourth, or any desired succeeding tap. The coincidence of the taps with their reflections can be fairly accurately observed, and a fairly accurate estimate formed of the velocity of sound, *i.e.* the velocity at which a compressing or rarefying of the air is propagated by the air. Instead of altering the distance of the source of sound from the reflector, we may ourselves move about between the source and the reflector, and we can find some places where the reflected taps occur simultaneously with the incident taps, and some places where they occur between the incident ones. This is pretty evident, for if we start from the source towards the reflector, as we approach it we get the reflected taps earlier and the incident ones later than when we were at the source. How far must we go towards the reflector in order that the original and reflected taps may again appear simultaneous? We must go half the distance that a tap is propagated during the interval between two taps: *half* the distance, because in going away from the source we are approaching the reflector and so make a double change—we not only get the original ones later, but we also get the reflected ones earlier, and so coincidence will have again been reached when we have gone half the distance between any pair of compressions travelling in the air. Now, if the taps succeed one another slowly, the distance in the air between any two of them travelling through it will be considerable; any one of them will go a considerable distance from the source before its successor is started after it. If, on the contrary, they succeed one another rapidly, the distance between the travelling taps will be small. In general, if V be the velocity with which a tap travels, and T be the interval of time between successive taps, the distance apart of the taps travelling in the air will be $\lambda = VT$. By arranging, then, that the taps shall succeed one another very rapidly, *i.e.* by making T small, we can arrange that λ may be small, and that consequently the distance between our source of sound and the reflecting wall may be small too, and yet large enough to contain several places at distances of $\frac{1}{2}\lambda$ apart between the source and the reflector where the incident and reflected taps occur simultaneously. Now, a very rapid succession of taps is to us a continuous sound, and where the incident and reflected taps coincide we hear simply an increased sound, while at the intermediate places where the incident taps occur in the intervals between the reflected taps we do not hear this effect at all. In the case of a succession of sharp taps we would hear in this latter place the octave of the original note, but if the original series be, instead of taps, a simple vibration of the air into and out from the reflector, the in and out motions of the incident waves will in some places coincide with the in and out motions of the reflected wave, and then there will be an increased motion, while at intermediate places the *in* and *out* motions of the incident wave will coincide with the *out* and *in* motions of the reflected wave, and no motion, or silence, will result, so that at some places the sound will be great and at intermediate places small. This whole effect of having an incident and reflected wave travelling simultaneously along a medium can be simply and beautifully illustrated to the eye, by sending a succession of waves along a chain or heavy limp rope or an india-rubber tube fixed at the far end so as to reflect the waves back again. It will then be found that the chain divides up into a series of places where the motion is very great, called loops, separated by points where the motion is very small, called nodes. The former are the places where the incident and reflected motions reinforce, while the latter are where these motions are opposed. If we measure the distance between two nodes, we know that it is half the distance a wave travels during a single vibration of the string, and so can calculate the velocity of the wave if we know the rate of vibration of the string. This is the second method mentioned above for finding the velocity of sound. There are so many things illustrated by this vibrating chain that it may be well to dwell on it for a few moments. We can make a wave travel up it, either rapidly or slowly, by stressing it much or little. If a wave travels rapidly, we must give it a very rapid vibration if we wish to have many loops and nodes between our source and the reflector; for the distance from node to node is half the distance a wave travels during a vibration, and if the wave goes fast the vibration must be rapid, or the distance from node to node will be too great for there to be many of them within the length of the chain. Another point to be observed is the way in which the chain moves when transmitting a single wave and when in this condition of loops and nodes, *i.e.* transmitting two sets of waves in opposite directions. There are two different motions of the parts of the chain it is worth considering separately. There is in the first place the displacement of any link up or down, and in the second place there is the rotation of a link on an axis which is at right angles to this up and down motion. Now, when waves are going up the chain those links are rotating most rapidly which are at any time most displaced: it is the links on the tops and bottoms of waves that are rotating most rapidly. On the other hand, in the case of loops and nodes the links in the middle of loops never rotate at all; they are much displaced up and down, but they keep parallel to their original direction all the time, while it is the links at the nodes where there is no displacement up and down that rotate first in one direction and then back again: there is, in the loops and nodes condition, a separation of the most rotating and the most displaced links which does not occur in the simple wave. There is a corresponding relation between the most rotated and the most rapidly moving links. These are the same links half-way up the simple waves, but in the loops and nodes the most rapidly moving links never rotate at all, while those at the nodes that get most rotated are not displaced at all. These remarks will be seen hereafter to throw light on some of the phenomena observed in connection with Hertz's experiments: hence their importance.

It will be observed that the method of measuring the velocity at which a disturbance is propagated along a string and which depends on measuring the distance between two nodes is really only a modification of the direct method of finding out how long a disturbance takes to go from one place to another; it is one in which we make the waves register upon themselves how long they took, and so does not require us to have at our disposal any method of sending a message from one place to another more quickly than the waves travel, and that is very important when we want to measure the rate at which disturbances travel that go as fast as light. If the wave travels very fast, we must have a very rapid vibration, unless we have a great deal of space at our disposal; for the distance between two nodes is half the distance the wave travels during one vibration, and so will be very long if the wave travels fast, unless the time of a vibration be very short. Hence, if we wish to make experiments in this way, in a moderate-sized room, on a wave that travels very fast, we must have a very rapid vibration to start the waves.

(*To be continued.*)

METEOROLOGY OF BEN NEVIS.[1]

THIS work, just issued by the Royal Society of Edinburgh as vol. xxxiv. of its Transactions, is a quarto volume of 467 pages, giving in detail the hourly observations at the Ben Nevis Observatory from December 1883 to the close of 1887, together with a log containing much that is interesting and novel in meteorological observing; the five daily observations made in connection therewith at Fort William, and a report by Dr. Buchan on the meteorology of Ben Nevis.

This is, it is believed, the only existing combined high and low level Observatories sufficiently near each other in horizontal distance as to be virtually one Observatory: completely placed in one of the greatest highways of storms in the world; and at such a height as to be occasionally above the storms that sweep over that part of Europe, and frequently, as the winds show, within a geographical distribution of pressure at this height widely different from what obtains at the same time at sea-

---

[1] "Meteorology of Ben Nevis." By Alexander Buchan, LL.D., Secretary of the Scottish Meteorological Society. Transactions of the Royal Society of Edinburgh, vol. xxxiv.